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(54) **Power measurement apparatus and method therefor**

(57) A known power test meter system, employing a self-adjusting impedance bridge comprises a first branch having one or more thermistors and a second branch having a selectively switchable 200Ω/100Ω resistance. The test meter system is used to calculate a so-called Voltage Reflection Coefficient (VRC) of a reference oscillator of a device under test. The VRC of the reference oscillator is used, in combination with the knowledge of a VRC of the test meter system to calculate power transfer between the reference oscillator and the test meter system, and ultimately to verify the output impedance of the reference oscillator. However, the temperature of the thermistor(s), in a sensor designed to operate at a 200Ω resistance, can rise above a predetermined temperature when the 100Ω resistance is in-circuit, resulting in inaccurate operation of, or even damage to, the thermistor(s). By using different resistances, advantage can be taken of the negative temperature coefficient of one or more thermistors (204, 206), resulting in temperature of the thermistor(s) (204, 206) operating within acceptable temperature limits.

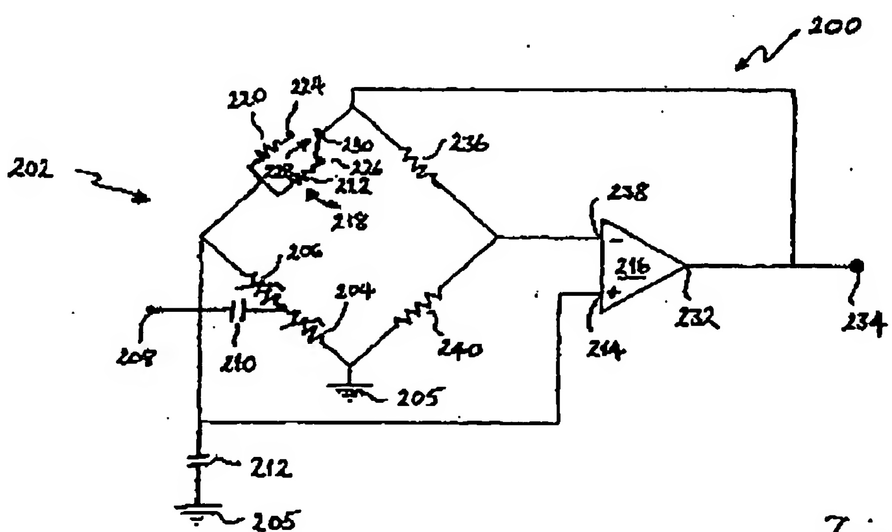

Figure 2.

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reference oscillator output signal to the test power meter. The mismatch uncertainty can therefore make a significant contribution to the overall uncertainty attributable to the measurement of the power level of the output signal mentioned above. Given the purpose served by reference oscillators, and more generally power reference sources, the mismatch uncertainty therefore needs to be maintained at a very low value. There is therefore clearly a need to calculate the mismatch uncertainty associated with the amount of power transferred from the reference oscillator to the test power meter, and so values for the load and source VRCs, Γ_L, Γ_S, need to be measured or calculated.

[0009] Whilst the VRC of the load (the test meter system) can be measured with relative ease using conventional methods, the VRC of the source (the reference oscillator) can only be established when the reference oscillator is active. As a result of the need for the reference source to be active, known measurement techniques, such as Vector Network Analysis (VNA), can not be used, because VNA relies upon a principle of applying a sinusoidal signal to the reference oscillator and measuring relative amplitude and phase of a reflected signal; the reflected signal will be distorted by the signal generated by the reference oscillator. It will therefore be impossible to measure accurately the proportion of the VNA signal that has been reflected, as the VNA signal and the signal generated by the reference oscillator are at a same frequency.

[0010] Another known technique is a so-called impedance bridge for measuring the output impedance of the reference oscillator. However, the signal generated by the reference oscillator will also interact with the impedance bridge in such a way as to render any measurement of the impedance of the reference oscillator inaccurate.

[0011] In order to obviate the above disadvantage of the impedance bridge measurement technique, another known measurement technique disclosed in the Agilent E4416A/E4417A Service Guide (Agilent Technologies Limited, E4416-90014) provides a way of measuring the source match using a modified impedance bridge. In particular, the technique employs an Agilent Technologies Inc 432A power meter having a self-adjusting impedance bridge, one branch of the impedance bridge comprising thermistors, the impedance of which can be altered by altering a switchable resistance, in an adjacent branch, between two settings: 200Ω and 100Ω. The switching of the resistance results in a consequential change in the impedance of the thermistors, and hence the VRC of the test meter system, or load. Consequently, a mechanism is provided to switch the load VRC, Γ_L, between two values, allowing the source VRC, Γ_S, to be calculated approximately, and verified by measurement using conventional means. Once the source VRC, Γ_S, is known, it is possible, using equation (2), to calculate the mismatch uncertainty, U, associated with the transfer of power from the reference oscillator to the 432A test power meter and with the adjustment of the output power of the reference oscillator.

[0012] However, some thermistors employed in sensor units have a negative temperature coefficient with respect to resistance. As a result, the temperature of the thermistor(s) rise(s) when the resistance of the thermistor(s) fall(s). This temperature rise can make the sensor unit less reliable, or can even damage the thermistor(s) and hence the sensor unit.

[0013] According to a first aspect of the present invention, there is provided a self-balancing impedance bridge circuit apparatus for measuring RF power, the apparatus comprising: a bridge circuit comprising a first branch connected to a second branch thereof; wherein the first branch comprises a sensor device having an impedance value and a temperature coefficient associated therewith, a temperature of the sensor device being related to the impedance value; the second branch comprises at least one electrical element capable of providing a selectable impedance value, the selectable impedance value biasing, when in use, the impedance value of the sensor device; and the selectable impedance value is such that the impedance value of the sensor device corresponds to the temperature of the sensor device not exceeding a predetermined temperature.

[0014] The temperature coefficient may be a negative temperature coefficient.

[0015] The sensor device may be a bolometric device, and in one possible embodiment the bolometric device may be a thermistor.

[0016] The at least one electrical element capable of providing the selectable impedance value may be switchable and/or the at least one electrical element capable of providing the selectable impedance value may be a network of impedances.

[0017] The network of impedances may comprise a first impedance, a second impedance, and a switch for connecting the first impedance or the second impedance in-circuit with respect to the bridge circuit.

[0018] The apparatus may further comprise another sensor device coupled to the sensor device. The sensor device may behave as series coupled to the another sensor device with respect to the bridge circuit, and the sensor device may behave as parallel coupled to the another sensor device, when an RF signal is applied at a node between the sensor device and the another sensor device.

[0019] The bridge circuit may further comprise: a third branch that may be coupled to a fourth branch, the third and fourth branches including a substantially same impedance; and the third branch may be coupled to the second branch and the fourth branch may be coupled to the first branch.

[0020] According to a second aspect of the present invention, there is provided a power meter and sensor unit comprising the apparatus as set forth above in accordance with the first aspect of the present invention.

self-adjusting impedance bridge 200. The first and second resistors 220, 222 and the two-way switch 228 constitute a second branch of the bridge circuit 202. Whilst resistors have been used in this example, other electrical elements capable of providing impedances can be employed in addition to or to replace the first and second resistors 220, 222.

[0034] The third terminal 230 of the two-way switch 218 is also coupled to a first terminal of a third resistor 236, for example a 1 kΩ resistor, a second terminal of the third resistor 236 being coupled to an inverting input terminal 238 of the operational amplifier 216. The third resistor 236 constitutes a third branch of the bridge circuit 202.

[0035] The second terminal of the third resistor 236 is also coupled to a first terminal of a fourth resistor 240, for example a 1kΩ resistor, a second terminal of the fourth resistor 240 being coupled to the first terminal of the first thermistor 204 and hence the earth 205.

[0036] In order, ultimately, to determine an uncertainty value, U, of the amount of power transferred from the reference source (the source) to the test system 102 (the load), a source VRC and a load VRC need to be calculated. As will be appreciated by a person skilled in the art, the load VRC is known approximately, by virtue of the knowledge of the values of the first and second resistances 220, 222 forming the impedance network 218, and the values of the third resistor 236 and fourth resistor 240. Alternatively, the load VRC can be measured by a conventional technique, for example, by using a VNA.

[0037] Therefore, it is necessary to carry out measurements in order to calculate the source VRC, Γ_s. The ability to vary the impedance value switched into the bridge circuit 202 at the second branch, results in an ability to vary the impedance of the first and second thermistors 204, 206, thereby causing the load VRC, Γ_L, to be varied as well. Hence, two different conditions under which power is delivered to the test power meter 108, or load, are provided.

[0038] It should be understood that the second compensation self-adjusting bridge (not shown) also comprises a corresponding secondary bridge circuit (not shown). The structure of the secondary bridge circuit is the same as the bridge circuit 202.

[0039] In order to understand how the above two conditions under which power can be delivered to the test power meter system 102 can be used to calculate the source VRC, Γ_s, and hence the mismatch uncertainty value, U, a mathematical basis for calculation of the source VRC, Γ_s, is set out below.

[0040] Based upon equation (1) above, if the load VRC can assume two different values, Γ_1 and Γ_2, and the two different values give rise to two different respective power measurements, P_1 and P_2 (the available powers remaining the same), the equation (1) can be expressed as:

$$P_{Z_0} = P_1 \frac{|1-\Gamma_S\Gamma_1|^2}{1-|\Gamma_1|^2} = P_2 \frac{|1-\Gamma_S\Gamma_2|^2}{1-|\Gamma_2|^2} \tag{3}$$

[0041] Rearranging equation (3):

$$\frac{P_1}{P_2}\frac{(1-|\Gamma_2|^2)}{(1-|\Gamma_1|^2)} = \frac{|1-\Gamma_S\Gamma_2|^2}{|1-\Gamma_S\Gamma_1|^2} \tag{4}$$

[0042] Given that P_1, P_2, Γ_1, Γ_2 can either be calculated or measured, the left side of equation (4) can be replaced by a factor, M, giving:

$$\sqrt{M} = \frac{|1-\Gamma_S\Gamma_2|}{|1-\Gamma_S\Gamma_1|} \tag{5}$$

[0043] Whilst equation (5) can not be directly solved for the source VRC, Γ_S, because the source VRC, Γ_S, is a complex quantity, an approximate solution using the two values of the load VRC, Γ_L, is:

$$|\Gamma_S| = \frac{\left|2|\Gamma_1|M-2|\Gamma_2|\right| \pm \sqrt{\left|2|\Gamma_2|-2|\Gamma_1|M\right|^2 - 4\left||\Gamma_1|^2 M-|\Gamma_2|^2\right||M-1|}}{2(|\Gamma_1|^2 M-|\Gamma_2|^2)} \tag{6}$$

[0044] Using equation (6) above, an adequately accurate result for the source VRC, Γ_S, can be obtained provided a phase angle of the reference source is within ±40% of 0° or ± 180°. Consequently, in order to be able to calculate the source VRC, Γ_S, the following measurement steps are carried out.

[0045] In operation, the sensor unit 104 is coupled to the reference source port 110 and the power meter 100 and

8. An apparatus as claimed in any one of the preceding claims. further comprising another sensor device (206) coupled to the sensor device (204).

9. An apparatus as claimed in Claim 8, wherein the sensor device (204) behaves as series coupled to the another sensor device (206) with respect to the bridge circuit, and the sensor device (204) behaves as parallel coupled to the another sensor device (206), when an RF signal is applied at a node between the sensor device (204) and the another sensor device (206).

10. An apparatus as claimed in any one of the preceding claims, wherein the bridge circuit (202) further comprises:

a third branch coupled to a fourth branch, the third and fourth branches including a substantially same impedance; and
the third branch is coupled to the second branch and the fourth branch is coupled to the first branch.

11. A method of measuring RF power for a self-adjusting impedance bridge (200), the method comprising the steps of:

setting (302) a selectable impedance value of a first branch of a bridge circuit (202) so as to bias an impedance of a sensor device (204) in a second branch of the bridge circuit (202) coupled to the first branch of the bridge circuit (202), a temperature of the sensor device (204) relating to the impedance of the sensor device (204); wherein
the sensor device (204) has a temperature coefficient associated therewith; and
the selectable impedance value is such that the impedance of the sensor (204) device corresponds to the temperature of the sensor device (204) not exceeding a predetermined temperature.

12. A method as claimed in Claim 11, wherein the temperature coefficient is a negative temperature coefficient.

13. A method as claimed in Claim 11 or Claim 12, wherein the sensor device (204) is a bolometric device.

14. A method as claimed in Claim 13, wherein the bolometric device is a thermistor (204).

15. A method as claimed in any one Claims 11 to 14. wherein the step of changing the selectable impedance value comprises the step of:

switching (306) the selectable impedance value between a first impedance value and a second impedance value so as to bias the impedance of the sensor device (204).

16. A method as claimed in Claim 15, wherein the selectable impedance value is provided by a network of impedances (218).

17. A method as claimed in Claim 16, wherein the network of impedances comprises a first impedance (220), a second impedance (222), and a switch (228); and the method further comprises the step of:

switching (306) the first impedance (220) or the second impedance (222) in-circuit with respect to the bridge circuit (202).

18. A method as claimed in any one of Claims 11 to 17, further comprising the step of:

providing another sensor device (206) coupled to the sensor device (204).

19. An method as claimed in Claim 18, wherein the sensor device (204) behaves as series coupled to the another sensor device (206) with respect to the bridge circuit (202), and the sensor device (204) behaves as parallel coupled to the another sensor device (206) when an RF signal is applied at a node between the sensor device (204) and the another sensor device (206).

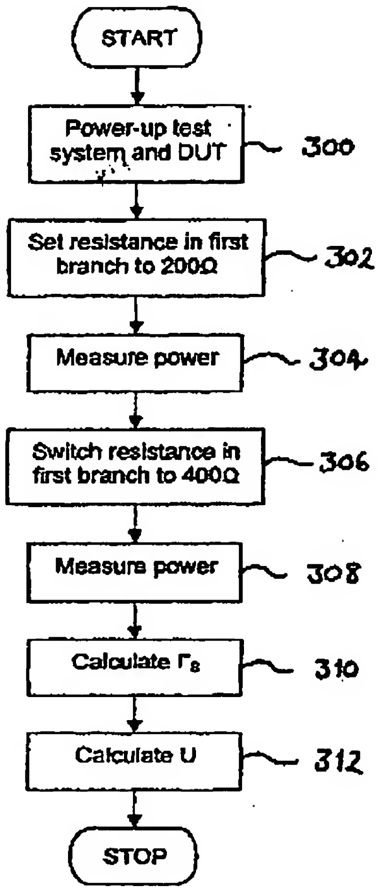
START
Power-up test system and DUT
300
Set resistance in first branch to 200Ω
302
Measure power
304
Switch resistance in first branch to 400Ω
306
Measure power
308
Calculate Γs
310
Calculate U
312
STOP

Figure 3

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 25 1632

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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01-08-2003

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3626290	A	07-12-1971	NONE	
GB 605734	A	29-07-1948	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82